MAP MF-1382-I

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MAPS SHOWING DISTRIBUTION OF IRON, COBALT, BARIUM, STRONTIUM, ARSENIC, ANTIMONY, AND BISMUTH IN SAMPLES OF MINUS-60-MESH (0.25-MM) STREAM SEDIMENT AND (OR) NONMAGNETIC HEAVY-MINERAL CONCENTRATE, WALKER LAKE 1° X 2° QUADRANGLE, CALIFORNIA AND NEVADA

By M.A. Chaffee, R.H. Hill, and S.J. Sutley

MISCELLANEOUS FIELD STUDIES MAP
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CHAFFEE AND OTHERS—Fe, Co, Ba, Sr, As, Sb, AND Bi IN STREAM SEDIMENT AND NONMAGNETIC HEAVY-MINERAL CONCENTRATE, WALKER LAKE 1° X 2° QUAD, CA-NV 1:250,000 MAP MF-1382-I

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DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-1382-I
SHEET 1 OF 3

MAP A. DISTRIBUTION OF IRON IN NONMAGNETIC HEAVY-MINERAL CONCENTRATE

EXPLANATION

E — SAMPLE LOCALITY AND BOUNDARY AND DOMINANT LITHOLOGY OF ASSOCIATED DRAINAGE BASIN--Anomalous in iron. Locality is at center of plotted symbol. Figure 1 shows concentration ranges represented by locality symbols. Letter indicates lithology keyed to table 1

Table 1.--Summary of the dominant source-rock type(s) present in the drainage basins upstream from the most metal-rich sample localities shown on the maps

[X indicates rock type present; leaders (--) indicate rock type not present in significant exposures in that area. Area H is considered to be anomalous only as a result of scrap-metal contamination]

Lithology symbol	Dominant rock types in area		
	Paleozoic and Mesozoic rocks	Mesozoic intrusive rocks	Tertiary volcanic rocks
A	X	X	X
B	X	X	--
C	X	--	X
D	--	X	X
E	X	--	--
F	--	X	--
G	--	--	X

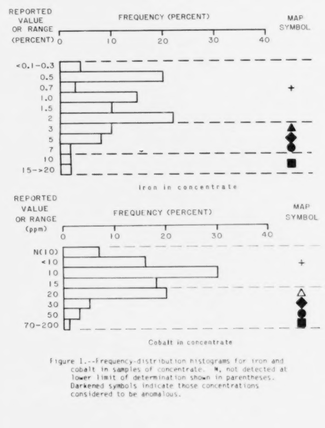


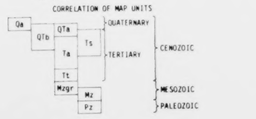
Figure 1.--Frequency-distribution histograms for iron and cobalt in samples of concentrate. N, not detected at lower limit of determination shown in parentheses. Darkened symbols indicate those concentrations considered to be anomalous.

EXPLANATION

B — SAMPLE LOCALITY AND BOUNDARY AND DOMINANT LITHOLOGY OF ASSOCIATED DRAINAGE BASIN--Anomalous in cobalt. Locality is at center of plotted symbol. Figure 1 shows concentration ranges represented by locality symbols. Letter indicates lithology keyed to table 1

Note: The following correlation and description of map units are for the geologic base map shown in gray

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Qa — ALLUVIAL, LACUSTRINE, EOLIAN, LANDSLIDE, AND GLACIAL DEPOSITS, UNDIVIDED (QUATERNARY)--As mapped locally includes uppermost Tertiary gravel

QTb — BASALT (QUATERNARY AND TERTIARY)--Ranges in age from about 9 m.y. to less than 1 m.y.

QTa — ANDESITE TO RHYOLITE (QUATERNARY AND TERTIARY)--Andesite flows and breccia. Minor rhyolitic flows and shallow intrusive rocks. Ranges in age from about 5 m.y. to less than 1 m.y.

Ts — SEDIMENTARY ROCKS (TERTIARY)--Tuffaceous sandstone, siltstone, and conglomerate to gravel. Minor tuff and volcanic breccia. Ranges in age from about 12 m.y. to 2 m.y.

Ta — ANDESITE TO RHYOLITE (TERTIARY)--Andesite flows and breccia. Minor rhyolitic flows and shallow intrusive rocks, latitic to rhyolitic ash-flow tuffs, and sedimentary rocks; sparse basalt; includes some intrusive rocks. Ranges in age from about 22 m.y. to 5 m.y.

Tt — TUFF (TERTIARY)--Welded and nonwelded rhyolitic ash-flow tuff. Minor rhyolite flows and shallow intrusive rocks, andesite flows, and sedimentary rocks; sparse basalt; includes some intrusive rocks. Ranges in age from 30 m.y. to 22 m.y.

Mzgr — GRANITIC ROCKS (MESOZOIC)--Granite to granodiorite. Minor dioritic, gabbroic, and felsic intrusive rocks

Mz — VOLCANIC AND SEDIMENTARY ROCKS, UNDIVIDED (MESOZOIC)--Andesitic to rhyolitic

best copy available

Base from U.S. Geological Survey, 1957; revised 1969

Geology simplified from Stewart and others, 1982

SCALE 1:250,000

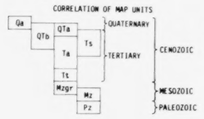
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

CONTOUR INTERVAL 200 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Note: The following correlation and description of map units are for the geologic base map shown in gray

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Qa ALLUVIAL, LACUSTRINE, EOLIAN, LANDSLIDE, AND GLACIAL DEPOSITS, UNDIVIDED (QUATERNARY)--As mapped locally includes uppermost tertiary gravel

Qb BASALT (QUATERNARY AND TERTIARY)--Ranges in age from about 9 m.y. to less than 1 m.y.

QTa ANDESITE TO RHYOLITE (QUATERNARY AND TERTIARY)--Andesite flows and breccia. Minor rhyolitic flows and shallow intrusive rocks. Ranges in age from about 5 m.y. to less than 1 m.y.

Ts SEDIMENTARY ROCKS (TERTIARY)--Tuffaceous sandstone, siltstone, and conglomerate to gravel. Minor tuff and volcanic breccia. Ranges in age from about 12 m.y. to 2 m.y.

Ta ANDESITE TO RHYOLITE (TERTIARY)--Andesite flows and breccia. Minor rhyolitic flows and shallow intrusive rocks, latitic to rhyolitic ash-flow tuffs, and sedimentary rocks; sparse basalt; includes some intrusive rocks. Ranges in age from about 22 m.y. to 5 m.y.

Tt TUFF (TERTIARY)--Welded and nonwelded rhyolitic ash-flow tuff. Minor rhyolite flows and shallow intrusive rocks, andesite flows, and sedimentary rocks; sparse basalt; includes some intrusive rocks. Ranges in age from 30 m.y. to 22 m.y.

Mzgr GRANITIC ROCKS (MESOZOIC)--Granite to granodiorite. Minor dioritic, gabbroic, and felsic intrusive rocks

Mz VOLCANIC AND SEDIMENTARY ROCKS, UNDIVIDED (MESOZOIC)--Andesitic to rhyolitic lava flows, breccia, tuff, volcanic sandstone, and conglomerate; shallow marine siltstone, sandstone, conglomerate, and limestone; continental sandstone and conglomerate. Metamorphosed near granitic rocks

Pz SEDIMENTARY AND VOLCANIC ROCKS, UNDIVIDED (PALEOZOIC)--Deep-water marine chert, phyllite, shale, carbonate rocks, volcanogenic turbidite, sandstone, and conglomerate (Ordovician, Devonian, Pennsylvanian, and Permian); shallow-water siltstone, sandstone, conglomerate, and carbonate (Cambrian, Mississippian, and Permian; as mapped includes upper Proterozoic rocks at one locality); and andesitic breccia and lava (Permian). Metamorphosed near granitic rocks

GEOLOGIC CONTACT

HIGH-ANGLE FAULT--Dotted where concealed

THRUST OR LOW-ANGLE FAULT

QUADRANGLE LOCATION

MAP B. DISTRIBUTION OF COBALT IN NONMAGNETIC HEAVY-MINERAL CONCENTRATE

INTRODUCTION

This report is part of a folio of maps of the Walker Lake 1° x 2° quadrangle, California and Nevada, prepared under the Conterminous United States Mineral Assessment Program. The folio includes geological, geochemical, and geophysical maps, as well as mineral resource assessment maps, which identify selected known or possible mineral-deposit environments in the quadrangle. The geochemical maps show the distributions of selected individual elements (Chaffee and others, 1988a, b, c) and the distributions of selected groups of elements (Chaffee, 1988a, b, c). Discussions accompanying the individual element maps are restricted to possible mineral residences of the individual elements as well as to what types of mineral deposits and environments may be represented by anomalies of a particular element. Discussions accompanying the multielement maps describe the types of mineral deposits that may be related to each element group and indicate the most favorable localities for these deposits.

This chapter of the folio shows the abundances and distributions of iron, cobalt, barium, strontium, arsenic, antimony, and bismuth in 1,116 samples of minus-60-mesh (0.25-mm) stream sediment and (or) 1,005 samples of nonmagnetic heavy-mineral concentrate derived from stream sediment. Analyses for 110 stream-sediment samples and 3 concentrate samples included in this report are from samples collected and analyzed during 1987 and 1988 for the Emigrant Basin Primitive Area study (Tooker and others, 1970). The rest of the samples were collected and analyzed during 1978 and 1979, specifically for the present report. A combined tabulation of all these analyses is published in Open-File Geological Survey (Open-file Report 80-881 (Chaffee and others, 1980). This same tabulation is also available on computer tape from the National Technical Information Service (McDanal and others, 1981).

GENERAL GEOLOGY

The Walker Lake quadrangle includes parts of two major physiographic provinces: the Sierra Nevada-Cascade Mountains and the Basin and Range province. These two provinces have contrasting geological frameworks that reflect their different geologic histories. Because the geology of the Walker Lake quadrangle is complex, only a brief generalized summary is given here.

Sierra Nevada-Cascade Mountains province

Most of the western one-third of the quadrangle is in the Sierra Nevada. The Sierra Nevada includes the major Sierra Nevada batholith, which is composed of plutons ranging from Permian(?) to Late Cretaceous in age (Kelth and Seltz, 1981). These plutons range from alaskite to gabbro in composition, with the bulk of the batholith being in the quartz monzonite to granodiorite range. This plutonic complex has intruded and metamorphosed a sequence of Paleozoic and Mesozoic rocks that comprise both clastic- and carbonate-rich sedimentary rocks as well as volcanic (and plutonic?) rocks. Overlying these older units locally are Tertiary volcanic rocks consisting of flows, breccias, and tuffaceous sedimentary rocks; sparse dikes, sills, and necks. Most of these Tertiary volcanic rocks are andesitic in composition; however, rocks of rhyolitic composition are present locally. Glacial and landslide deposits are present locally in many of the valleys in the Sierra Nevada.

Basin and Range province

Most of the eastern two-thirds of the quadrangle is in the Basin and Range physiographic province. Much of this part of the quadrangle contains thick sequences of extensively block-faulted Paleozoic and Mesozoic sedimentary rocks of widely varying compositions. Mesozoic plutons, which range in composition from alaskite to gabbro but are predominantly in the granite to granodiorite range, have intruded and locally metamorphosed the overlying sedimentary rocks. A long history of Tertiary volcanism is recorded in the eastern part of the quadrangle; thick sequences of flows, breccias, and tuffs, ranging in composition from rhyolite to basalt, are found throughout much of the area. Tertiary and Quaternary volcanic flows, breccias, and shallow intrusive rocks, ranging in composition from rhyolite to basalt, are also present locally. Alluvial, lacustrine, and eolian sedimentary deposits are present in most of the valleys in this part of the quadrangle.

Geologic base for the geochemical maps

A simplified geologic base map of the Walker Lake quadrangle has been used with each of the accompanying geochemical maps. A more detailed geologic map of the quadrangle is available as a separate chapter in this Walker Lake folio (Stewart and others, 1982). For purposes of discussion in this report, some of the geologic units shown on the geologic map of Stewart and others (1982) have been consolidated into three major units.

Paleozoic and Mesozoic rocks--All of the pre-Cretaceous (Paleozoic and Mesozoic) igneous and sedimentary rock units (units Pz and Mz on map) have been consolidated into this one unit. Many but not all of these rocks have been metamorphosed.

Mesozoic intrusive rocks--Plutons ranging in composition from alaskite to gabbro compose this unit (unit Mzgr on map).

Tertiary volcanic rocks--This unit is composed predominantly of flow rocks of andesitic composition, but it also includes necks and flows ranging in composition from rhyolite to basalt as well as felsic to intermediate tuffs (includes units Tt and Ta on map).

ECONOMIC GEOLOGY

The Walker Lake quadrangle contains many mines and prospects. As a result of the complex geologic history of the area, many different mineral-deposit environments exist within the quadrangle. On the basis of geological and geochemical studies conducted for the reports in this folio, as well as on the recorded mining in the region, the commodities thought to have the greatest resource potential within the Walker Lake quadrangle are copper, lead, zinc, gold, silver, molybdenum, tungsten, and uranium. Thus, this geochemical study emphasizes those elements and element suites that may prove useful in locating areas containing (1) base and precious metals[1] and tungsten in vein or contact-metasomatic deposits, (2) copper and (or) molybdenum porphyry-type deposits, and (3) disseminated gold deposits. Studies related to uranium deposits are described elsewhere (Durham and Felmlee, 1982; Fay and Jones, 1980).

NATURE AND SCOPE OF THE GEOCHEMICAL SAMPLING

The geochemical sampling program for the Walker Lake quadrangle was based on collecting as many as three different types of samples--rock, minus-60-mesh stream sediment, and nonmagnetic heavy-mineral concentrate derived from stream sediment--at preselected locations throughout the quadrangle. Most of the samples of alluvial material were collected from first-order (unbranched) and second-order (below the junction of two first-order) stream channels as shown on 1:62,500-scale topographic maps.

The chemical analyses of the samples of stream sediment and concentrate provide information that may be used by the evaluator to separate the background concentrations of the seven elements discussed in this chapter of the folio from their anomalous concentrations. Anomalous concentrations may indicate the presence of as yet unknown mineral deposits that may be either exposed or buried. Plots of the analyses can be used to delineate those areas where samples have been found to contain anomalous concentrations of one or more elements commonly associated with ore processes.

Many anomalies shown on the accompanying maps are related to known mining activity. Some known mineral deposits are not reflected by anomalies, however, primarily because they are not close to sampled stream channels but also because not all samples collected were truly representative of the material being eroded upstream from the sample site. Because the sampling was designed and executed on a reconnaissance scale, some relatively small but exposed areas of anomalous rock may not have been detected despite proximity to sampled stream channels. Mineral deposits not exposed at the surface may not be easily detected even if part of the deposit system, such as an alteration aureole, is exposed. Additional detailed geochemical surveys would be necessary to identify and delineate specific mineralized areas.

Deposits of both placer minerals and saline, playa-associated minerals have been mined in the past in many of the alluvium-filled valleys and basins scattered throughout the Walker Lake quadrangle. The sampling program for the present study was designed primarily to evaluate areas of outcrop; thus, mineral deposits that may be present in alluvial-filled valleys and basins are excluded from consideration in this geochemical report.

DESCRIPTION OF THE SAMPLE MEDIA

Sediment was collected from active stream channels and processed to produce the minus-60-mesh stream-sediment and the nonmagnetic heavy-mineral-concentrate samples. Unlike rock samples, which represent a restricted, essentially point source, the sediment collected at a given site is considered to represent a composite of outcrop material eroded from the entire drainage basin upstream from the collection site.

The stream-sediment samples provide information about the elements in all of the minerals present in the eroded rock materials. In contrast, the concentrate samples provide information about the elements in only a limited number of minerals. The concentrating process removes most of the quartz, feldspar, clay minerals, and highly magnetic minerals. This selective concentration of minerals commonly related to mineral deposits permits determination of some elements that are not commonly detected in stream-sediment samples by emission spectroscopy. The concentrate chemistry may also be specific for certain minerals. For example, the concentration of barium in a stream-sediment sample represents the sum of barium contained in barite plus barium contained in potassium feldspars and possibly other minerals. Because of the processing procedures used, the barium in a concentrate sample represents predominantly the single mineral barite.

SAMPLE PREPARATION AND ANALYSIS

Sample preparation

The stream-sediment samples were composited from active alluvium collected from several locations within a 50-ft (15-m) radius of the localities shown on the accompanying maps. Each resulting sample was air-dried and then sieved. The material passing a screen with 0.25-mm openings (a 60-mesh screen) was saved and pulverized.

[1]The term base metals in this report includes some or all of the elements antimony, arsenic, bismuth, cadmium, copper, lead, and zinc. The precious metals are silver and gold.

The concentrate samples were processed from the same composited active alluvium material collected for the minus-60-mesh stream-sediment samples. The material was wet-panned until most of the quartz, feldspar, organic material, and clay-sized material was removed. The samples were air-dried, and the highly magnetic material was removed using a magnet. Any light material remaining in the concentrate was then separated by allowing the heavier fraction of the sample to settle through bromoform (specific gravity 2.86). The resulting heavy-mineral fraction was then separated into a magnetic and a relatively nonmagnetic fraction using a Frantz Isodynamic Separator[2] set at 0.6 ampere, with 15° forward and 15° side settings. The resulting nonmagnetic fraction was pulverized in an agate mortar.

Sample analysis

Both stream-sediment and nonmagnetic heavy-mineral-concentrate samples were analyzed for 31 elements (Ag, As, Au, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, La, Mg, Mn, Mo, Nb, Ni, Pb, Sb, Sc, Sn, Sr, Th, Ti, V, W, Y, Zn, and Zr) using a six-step semiquantitative emission spectrographic method (Grimes and Marranzino, 1968). Because of the limited amount of sample material, the concentrate samples were only analyzed spectrographically. The stream-sediment samples were also analyzed for arsenic by colorimetry (Ward and others, 1963), for zinc, antimony, and gold by atomic-absorption spectrometry (Ward and others, 1969; Welsch and Chao, 1975; Meier, 1980), and for cadmium and bismuth from a single solution by atomic-absorption spectrometry (Viets, 1978). Analyses for both sample types were performed partly in the field in a mobile chemistry laboratory and partly in U.S. Geological Survey laboratories near Golden, Colo.

The spectrographic analytical values are reported as the approximate geometric midpoints (0.15, 0.2, 0.3, 0.5, 0.7, and 1.0, or appropriate powers of ten of these values) of concentration ranges whose respective boundaries are 0.12, 0.18, 0.26, 0.38, 0.54, and 1.2 (or appropriate powers of ten of these values). In general, the precision of the spectrographic method is plus or minus one reporting value of the value given by the analyst approximately 83 percent of the time and plus or minus two reporting values of the value given by the analyst 96 percent of the time (Motooka and Grimes, 1976). A reference standard sample was analyzed with each batch of field samples to monitor the quality of the analyses.

For the six elements analyzed by colorimetry or atomic-absorption spectrometry, the reporting values vary with the element and with the concentration level for any given element. Precision for these analytical methods is commonly reported as a percent relative standard deviation and is based on replicate analyses of samples selected to provide information at different concentration levels. In general, the precision for each method tends to be lowest for those samples containing a given element at or near its lower limit of determination. For the six elements discussed in the geochemical chapters of this folio, the reported ranges of percent relative standard deviation (RSD) are as follows:

Element	Range of percent RSD	Source of data
As	0.0-48.9	Unpublished analyses
Zn	3.4-30.2	Ward and others, 1969, p. 21
Sb	3.7-10.7	Welsch and Chao, 1975
Au	0.0-22.8	Meier, 1980
Cd	3.3-18.8	Viets, 1978
Bi	1.4-4.0	Viets, 1978

As an example to use in interpreting these ranges, one might consider antimony, whose range is shown as 3.7-10.7 percent RSD. This range indicates that a reported antimony value should be within ± 10.7 percent (usually much less) of the mean value for the sample.

EVALUATION OF THE CHEMICAL ANALYSES

Of the 37 elements determined in the stream-sediment samples, 12 elements (Ag, As, Au, Bi, Cd, Cu, Mo, Pb, Sb, Sn, W, and Zn) were selected as those most likely to be associated with hydrothermal alteration and (or) mineralization of the types known or thought to exist in the Walker Lake quadrangle. Of the 31 elements determined in the concentrate samples, 17 elements (Ag, As, Au, B, Ba, Bi, Cd, Co, Cu, Fe, Mo, Pb, Sb, Sn, Sr, W, and Zn) were selected as possibly having the same associations. This chapter of the folio shows distribution plots of the analyses for bismuth and antimony determined by atomic-absorption spectrometry and arsenic determined by colorimetry, all in the stream-sediment samples, and for arsenic, barium, bismuth, cobalt, iron, antimony, and strontium determined by emission spectroscopy in the concentrate samples.

To simplify plotting of the analytical information, all reported values for each element were assigned to a category with a symbol that could be plotted by a computer program available in the U.S. Geological Survey STATPAC system (VanTrump and Miesch, 1977). The analyses for approximately 85 to 90 percent of the samples in each element population were considered to be clearly within the background range. With the exception of arsenic and antimony in concentrate samples, the rest of the analyses for each element have been placed into categories representing one or more reporting values.

[2]The use of trade names in this report is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

The reporting values and corresponding plotted symbols for each element are shown on the frequency-distribution histograms for each element (figs. 1-5).

On the basis of a study of the frequency-distribution histogram for each element population and the areal distribution of the analytical values for each element, we have selected what we feel is the best threshold value for that element. Symbols on the maps and histograms representing anomalous concentrations have been darkened, and the drainage basins upstream from these plotted symbols have been outlined on the maps. The different symbols have been plotted on each map so that a user can see the actual distributions of analytical value(s) for the samples and can therefore select a different threshold value, if desired.

The eight maps (A-H) in this chapter of the folio show the distributions of seven different elements in one or two sample media, and the following text includes a description of the significance of the anomalies for each element. Maps in other chapters of this folio show additional single-element or multielement distributions (Chaffee, 1988a, b, c; Chaffee and others, 1988a, b, c). The single-element maps show the localities of all samples, the concentrations present for the more anomalous samples, and the probable major source-rock type(s) upstream from each anomalous sample locality. The multielement maps identify specific localities that might represent favorable areas for certain types of mineral deposits containing the individual elements discussed in this chapter of the folio.

From a mineral potential standpoint, the most significant localities on maps A-H are those that have samples contain (1) more than one anomalous element, (2) concentrations for each anomalous element in the high end of the range shown on the accompanying histograms, and (or) (3) anomalies of a given element in both the stream sediment and concentrate, where both types of samples have been analyzed for that element.

DISCUSSION OF THE ELEMENTS

Iron and Cobalt

Maps A and B show the distributions of iron and cobalt, respectively, in concentrate samples. Because of the procedure used in processing the concentrate samples, the iron in concentrate samples most commonly occurs as the mineral pyrite. Lesser amounts of iron may be related to other minerals, such as arsenopyrite or rutile. Because the iron in this type of sample is largely related to pyrite, the iron content is a useful guide to hydrothermally altered (pyritized) areas related to many types of mineral deposits in the Walker Lake quadrangle. Most of the anomalous drainage basins outlined on map A were observed in the field to contain pyrite.

Cobalt can substitute for several different elements in mineral structures but is commonly found replacing Fe^{2+} in iron-rich sulfide and accessory minerals (Goldschmidt, 1958). Thus, cobalt in a stream-sediment sample normally includes the cobalt present in pyrite and arsenopyrite as well as the cobalt present in magnetite, hornblende, biotite, and other rock-forming minerals that are removed in processing a nonmagnetic concentrate. Because many of these minerals may not be related to hydrothermal mineralization, the distribution of cobalt in stream-sediment samples has not proved useful for mineral assessment studies in the Walker Lake quadrangle. Cobalt in a concentrate sample, however, is considered to be predominantly cobalt that has substituted for iron in pyrite and, to a lesser extent, arsenopyrite. Thus cobalt, like iron, can be considered a useful element for identifying pyritized areas. This indirect evidence is corroborated by the fact that many of the areas associated with anomalous cobalt samples were observed in the field to contain pyrite.

A comparison of the iron and cobalt contents in concentrate samples from drainage basins that have contrasting lithologies indicates that neither iron nor cobalt concentrations are affected significantly by any particular rock type. Both iron and cobalt anomalies are most commonly associated with Tertiary andesite flow units and, locally, with tuffaceous formations. To a lesser extent these anomalies are also associated with the Paleozoic and Mesozoic rocks. Field observations indicate that outcrops in most of these anomalous areas are clearly pyritized. Concentrate samples containing anomalous iron but not anomalous cobalt seem to occur locally in some areas of the Mesozoic intrusive rocks. The source of the iron is not known.

The outlines of the drainage basins containing anomalous samples (maps A and B) indicate that iron and cobalt are particularly enriched in certain parts of the Walker Lake quadrangle. Descriptions of many of these anomalous areas are given in the discussions accompanying the multielement geochemical maps (Chaffee, 1988a, b, c).

Barium and Strontium

Maps C and D show the distributions of barium and strontium, respectively, in concentrate samples. The barium and strontium concentrations in stream-sediment samples are the sum of their concentrations as trace elements in feldspars and other common rock-forming minerals plus their concentrations in the mineral barite. In concentrate samples, however, the rock-forming minerals have been removed; thus, the barium, and probably most of the strontium, occur predominantly in the mineral barite. Barite in the Walker Lake quadrangle occurs both as sedimentary barite and as hydrothermal barite; consequently, barium and strontium can be used to locate both bedded barite occurrences and areas of barite-associated hydrothermal alteration.

A comparison of barium and strontium concentrations in samples from drainage basins that have contrasting lithologies indicates that the background ranges for these two elements are generally higher in the Tertiary volcanic rocks and the Paleozoic and Mesozoic rocks as compared to the Mesozoic intrusive rocks. Known bedded barite localities are restricted to the relatively small areas of Paleozoic sedimentary rocks in the extreme southeastern part of the quadrangle; thus, most of the barium and strontium anomalies are thought to be related to hydrothermal barite. Hydrothermal barite can be an indicator of many different types of mineral deposits in the Walker Lake quadrangle, including base- and precious-metal contact-metasomatic and porphyry-type deposits.

The outlines of the drainage basins containing anomalous samples (maps C and D) indicate that barium is enriched in many parts of the Walker Lake quadrangle, particularly where hydrothermally altered Tertiary volcanic rocks crop out. The strongest barium anomalies are generally clustered and are less widespread than are those of barium. Descriptions of many of these anomalous areas are given in the discussions accompanying the multielement geochemical maps (Chaffee, 1988a, b, c).

Arsenic and Antimony

Maps E and F show the distributions of arsenic and antimony, respectively, in stream-sediment and concentrate samples. Concentrations of these two elements in concentrate samples were generally below the lower limit of determination of the spectrographic analytical method used for this study; consequently, very few analyses for these two elements in concentrate samples are available for plotting.

The mineral residences of arsenic and antimony determined in this study are not known. Arsenic is commonly found in arsenopyrite, but is also present in many complex sulfide minerals in association with base and precious metals. Arsenic may also substitute for sulfur in some common sulfide minerals such as pyrite, galena, and chalcopyrite (Goldschmidt, 1958). In general, antimony is found proxying for arsenic in sulfide minerals. Antimony can also substitute for lead in minerals such as galena (Goldschmidt, 1958).

In the Walker Lake quadrangle, arsenic and antimony anomalies should be useful in locating many types of deposits, particularly base- and precious-metal vein deposits, but also contact-metasomatic deposits, and possibly porphyry-type deposits. Both arsenic and antimony have been used as pathfinder elements in the search for various types of gold deposits.

A comparison of arsenic and antimony concentrations in samples from drainage basins that have contrasting lithologies indicates that arsenic and antimony concentrations in either sample medium are not influenced by differing rock types. Most of the arsenic and antimony anomalies are associated with either the Tertiary volcanic rocks or the Paleozoic and Mesozoic rocks.

The outlines of the drainage basins containing anomalous samples (maps E and F) indicate that arsenic and antimony are particularly enriched in certain parts of the Walker Lake quadrangle. Descriptions of many of these anomalous areas are given in the discussions accompanying the multielement geochemical maps (Chaffee, 1988a, b, c).

Bismuth

Maps G and H show the distributions of bismuth in stream-sediment and concentrate samples, respectively. The mineral or minerals containing bismuth in the Walker Lake study area are not known. Bismuth is commonly found in galena and along with arsenic and antimony in simple or complex sulfides, or sulfosalts. Bismuth is also associated with rare-earth minerals, especially in pegmatites (Goldschmidt, 1958). Bismuth is often found associated with tin, tungsten, and molybdenum deposits (Boyle, 1974).

Bismuth anomalies might be useful in locating many types of mineral deposits in the Walker Lake quadrangle, such as base- and precious-metal deposits, contact-metasomatic tungsten deposits, and porphyry molybdenum deposits.

A comparison of the bismuth concentrations in samples from drainage basins with contrasting lithologies indicates that bismuth concentrations in either sample medium are not influenced by rock type. Bismuth anomalies are present in the Paleozoic and Mesozoic rocks, the Tertiary volcanic rocks and, to a lesser extent, the Mesozoic intrusive rocks.

The outlines of the drainage basins containing anomalous samples (maps G and H) indicate that bismuth is particularly enriched in certain parts of the Walker Lake quadrangle. Stream-sediment anomalies for bismuth in many cases do not coincide with those for concentrate samples, suggesting that bismuth might be enriched in one mineral in the stream-sediment samples and in a different mineral in the concentrate samples. Descriptions of many of these anomalous areas are given in the discussions accompanying the multielement geochemical maps (Chaffee, 1988a, b, c).

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MAPS SHOWING DISTRIBUTION OF IRON, COBALT, BARIUM, STRONTIUM, ARSENIC, ANTIMONY, AND BISMUTH IN SAMPLES OF MINUS-60-MESH (0.25-MM) STREAM SEDIMENT AND (OR) NONMAGNETIC HEAVY-MINERAL CONCENTRATE, WALKER LAKE 1° X 2° QUADRANGLE, CALIFORNIA AND NEVADA

By

M.A. Chaffee, R.H. Hill, and S.J. Sutley

1988

AUTHOR: GEOLOGICAL SURVEY, RESTON, VIRGINIA - 1988

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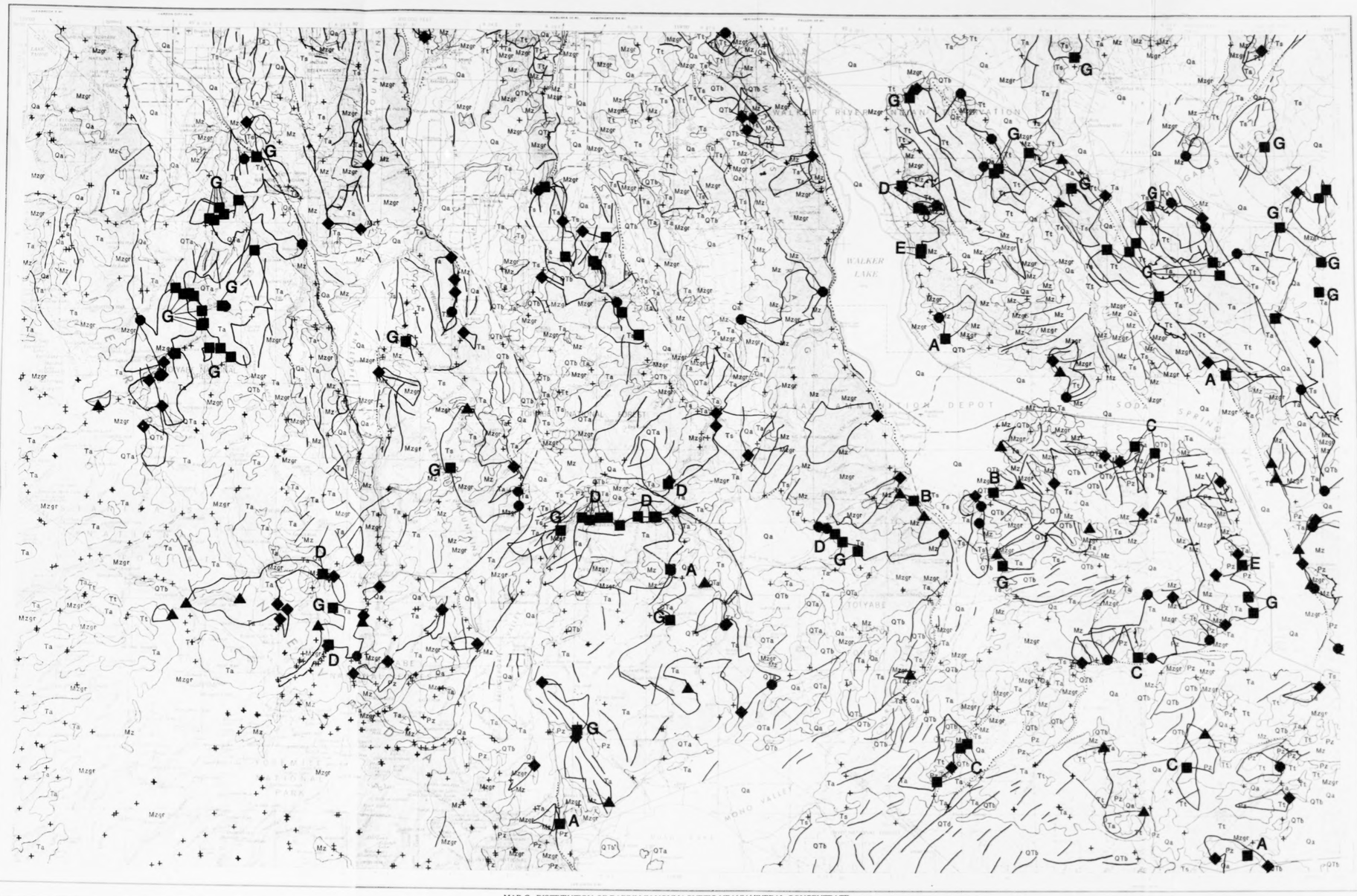
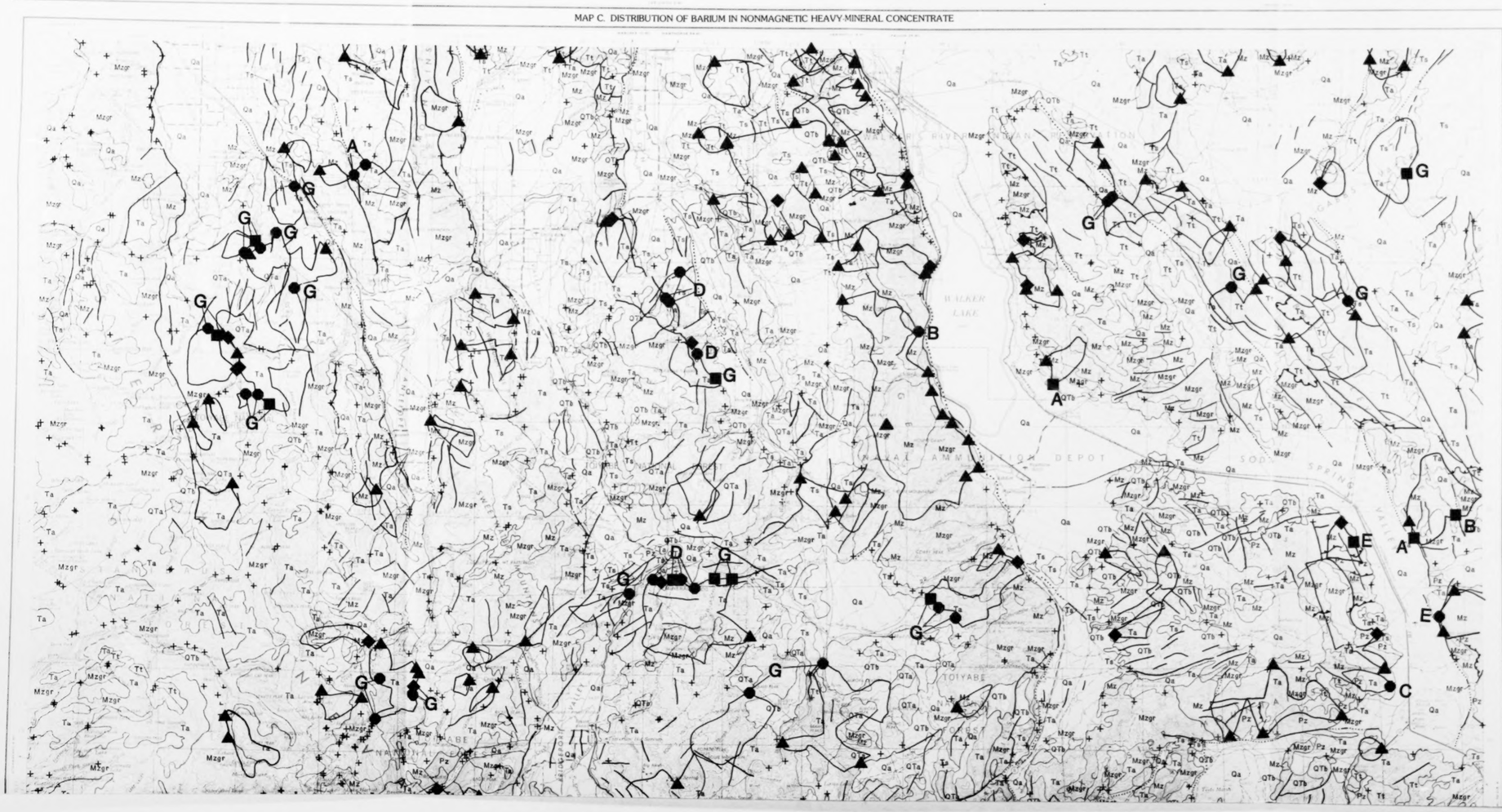


MAP C. DISTRIBUTION OF BARIUM IN NONMAGNETIC HEAVY MINERAL CONCENTRATE



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MAP C. DISTRIBUTION OF BARIUM IN NONMAGNETIC HEAVY-MINERAL CONCENTRATE

EXPLANATION

SAMPLE LOCALITY AND BOUNDARY AND DOMINANT LITHOLOGY OF ASSOCIATED DRAINAGE BASIN--Anomalous in barium. Locality is at center of plotted symbol. Figure 2 shows concentration ranges represented by locality symbols. Letter indicates lithology keyed to table 1

Table 1.--Summary of the dominant source-rock type(s) present in the drainage basins upstream from the most metal-rich sample localities shown on the maps

[X indicates rock type present; leaders (--) indicate rock type not present in significant exposures in that area. Area H is considered to be anomalous only as a result of source-metal contamination]

Lithology symbol	Dominant rock types in area		
	Paleozoic and Mesozoic rocks	Mesozoic intrusive rocks	Tertiary volcanic rocks
A	X	X	X
B	X	X	--
C	X	--	X
D	--	X	X
E	X	--	--
F	--	X	--
G	--	--	X

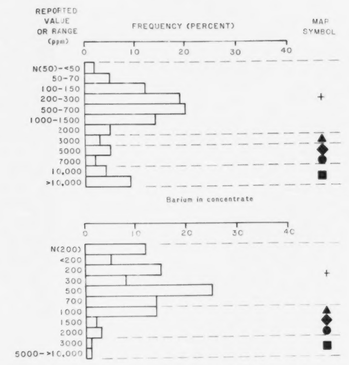


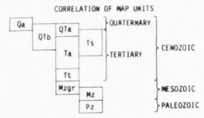
Figure 2.--Frequency-distribution histograms for barium and strontium in samples of concentrate. N, not detected at lower limit of determination shown in parentheses. Darkened symbols indicate those concentrations considered to be anomalous.

EXPLANATION

SAMPLE LOCALITY AND BOUNDARY AND DOMINANT LITHOLOGY OF ASSOCIATED DRAINAGE BASIN--Anomalous in strontium. Locality is at center of plotted symbol. Figure 2 shows concentration ranges represented by locality symbols. Letter indicates lithology keyed to table 1

Note: The following correlation and description of map units are for the geologic base map shown in gray

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Qa ALLUVIAL, LACUSTRINE, EOLIAN, LANDSLIDE, AND GLACIAL DEPOSITS, UNDIVIDED (QUATERNARY)--As mapped locally includes uppermost Tertiary gravel

QTb BASALT (QUATERNARY AND TERTIARY)--Ranges in age from about 9 m.y. to less than 1 m.y.

QTa ANDESITE TO RHYOLITE (QUATERNARY AND TERTIARY)--Andesite flows and breccia. Minor rhyolitic flows and shallow intrusive rocks. Ranges in age from about 5 m.y. to less than 1 m.y.

Ts SEDIMENTARY ROCKS (TERTIARY)--Tuffaceous sandstone, siltstone, and conglomerate to gravel. Minor tuff and volcanic breccia. Ranges in age from about 12 m.y. to 2 m.y.

Ta ANDESITE TO RHYOLITE (TERTIARY)--Andesite flows and breccia. Minor rhyolitic flows and shallow intrusive rocks, latitic to rhyolitic ash-flow tuffs, and sedimentary rocks; sparse basalt; includes some intrusive rocks. Ranges in age from about 22 m.y. to 5 m.y.

Tt TUFF (TERTIARY)--Welded and nonwelded rhyolitic ash-flow tuff. Minor rhyolite flows and shallow intrusive rocks, andesite flows, and sedimentary rocks; sparse basalt; includes some intrusive rocks. Ranges in age from 30 m.y. to 22 m.y.

Mzgr GRANITIC ROCKS (MESOZOIC)--Granite to granodiorite. Minor dioritic, gabbroic, and felsic intrusive rocks

Mz VOLCANIC AND SEDIMENTARY ROCKS, UNDIVIDED (MESOZOIC)--Andesitic to rhyolitic lava flows, breccia, tuff, volcanic sandstone, and conglomerate; shallow marine siltstone, sandstone, conglomerate, and limestone; continental sandstone and conglomerate. Metamorphosed near granitic rocks

Pz SEDIMENTARY AND VOLCANIC ROCKS, UNDIVIDED (PALEOZOIC)--Deep-water marine chert, phyllite, shale, carbonate rocks, volcanogenic turbidite, sandstone, and conglomerate (Ordovician, Devonian, Pennsylvanian, and

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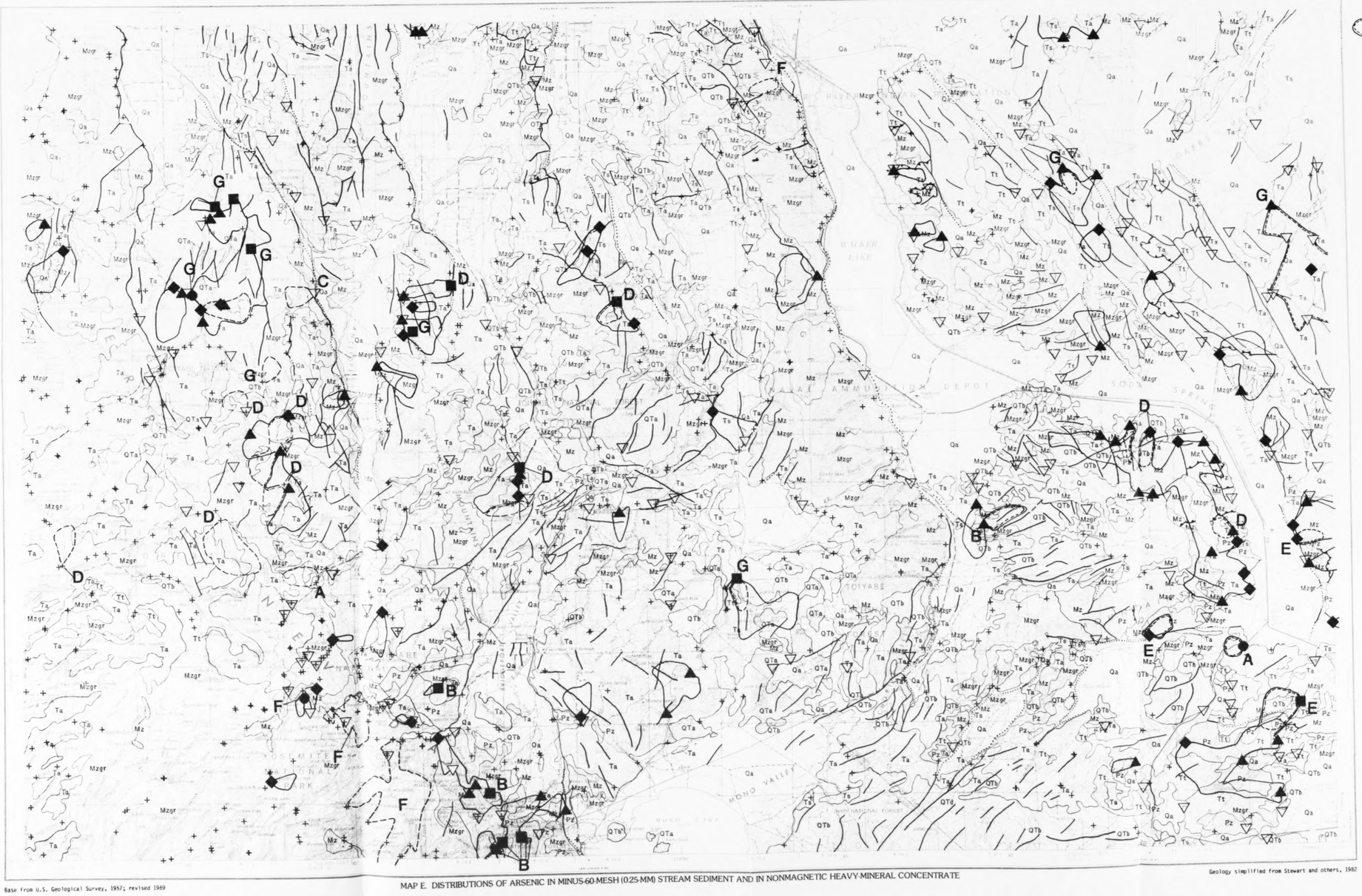
MAP D. DISTRIBUTION OF STRONTIUM IN NONMAGNETIC HEAVY-MINERAL CONCENTRATE



MAPS SHOWING DISTRIBU
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Base from U.S. Geological Survey, 1957; revised 1969

MAP E. DISTRIBUTIONS OF ARSENIC IN MINUS-60-MESH (0.25-MM) STREAM SEDIMENT AND IN NONMAGNETIC HEAVY-MINERAL CONCENTRATE

Geology simplified from Stewart and others, 1982

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MAP D. DISTRIBUTION OF STRONTIUM IN NONMAGNETIC HEAVY MINERAL CONCENTRATE

Note: The following correlation and description of map units are for the geologic base map shown in gray

CORRELATION OF MAP UNITS

Qa	QTa	QUATERNARY	CENOZOIC
QTb	Ts	TERTIARY	
	Ta		
	Tt		
Mzgr	Mz		MESOZOIC
	Pz		PALEOZOIC

DESCRIPTION OF MAP UNITS

Qa ALLUVIAL, LACUSTRINE, EOLIAN, LANDSLIDE, AND GLACIAL DEPOSITS, UNDIVIDED (QUATERNARY)--As mapped locally Includes uppermost Tertiary gravel

QTb BASALT (QUATERNARY AND TERTIARY)--Ranges in age from about 9 m.y. to less than 1 m.y.

QTa ANDESITE TO RHYOLITE (QUATERNARY AND TERTIARY)--Andesite flows and breccia. Minor rhyolitic flows and shallow intrusive rocks. Ranges in age from about 5 m.y. to less than 1 m.y.

Ts SEDIMENTARY ROCKS (TERTIARY)--Tuffaceous sandstone, siltstone, and conglomerate to gravel. Minor tuff and volcanic breccia. Ranges in age from about 12 m.y. to 2 m.y.

Ta ANDESITE TO RHYOLITE (TERTIARY)--Andesite flows and breccia. Minor rhyolitic flows and shallow intrusive rocks, latitic to rhyolitic ash-flow tuffs, and sedimentary rocks; sparse basalt; Includes some intrusive rocks. Ranges in age from about 22 m.y. to 5 m.y.

Tt TUFF (TERTIARY)--Welded and nonwelded rhyolitic ash-flow tuff. Minor rhyolite flows and shallow intrusive rocks, andesite flows, and sedimentary rocks; sparse basalt; Includes some intrusive rocks. Ranges in age from 30 m.y. to 22 m.y.

Mzgr GRANITIC ROCKS (MESOZOIC)--Granite to granodiorite. Minor dioritic, gabbroic, and felsic intrusive rocks

Mz VOLCANIC AND SEDIMENTARY ROCKS, UNDIVIDED (MESOZOIC)--Andesitic to rhyolitic lava flows, breccia, tuff, volcanic sandstone, and conglomerate; shallow marine siltstone, sandstone, conglomerate, and limestone; continental sandstone and conglomerate. Metamorphosed near granitic rocks

Pz SEDIMENTARY AND VOLCANIC ROCKS, UNDIVIDED (PALEOZOIC)--Deep-water marine chert, phyllite, shale, carbonate rocks, volcanogenic turbidite, sandstone, and conglomerate (Ordovician, Devonian, Pennsylvanian, and Permian); shallow-water siltstone, sandstone, conglomerate, and carbonate (Cambrian, Mississippian, and Permian; as mapped Includes upper Proterozoic rocks at one locality); and andesitic breccia and lava (Permian). Metamorphosed near granitic rocks

GEOLOGIC CONTACT

HIGH-ANGLE FAULT--Dotted where concealed

THRUST OR LOW-ANGLE FAULT

EXPLANATION

E SAMPLE LOCALITY AND BOUNDARY AND DOMINANT LITHOLOGY OF ASSOCIATED DRAINAGE BASIN--Anomalous in arsenic. Locality is at center of plotted symbol. Figure 3 shows concentration ranges represented by locality symbols. Solid outline indicates stream-sediment anomaly; dashed outline indicates concentrate anomaly (arsenic - N(500) ppm in concentrate samples). Letter indicates lithology keyed to table 1

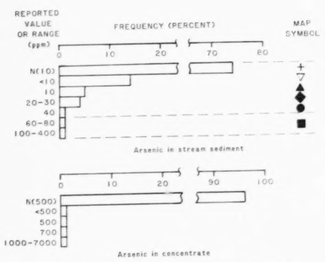

Figure 3.--Frequency-distribution histograms for arsenic in samples of stream sediment and concentrate. N, not detected at lower limit of determination shown in parentheses. Darkened symbols indicate those concentrations considered to be anomalous.

QUADRANGLE LOCATION

SCALE 1:250 000

CONTOUR INTERVAL 200 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

MAP E. DISTRIBUTIONS OF ARSENIC IN MINUS-60-MESH (0.25-MM) STREAM SEDIMENT AND IN NONMAGNETIC HEAVY-MINERAL CONCENTRATE

Geology simplified from Stewart and others, 1982

MAPS SHOWING DISTRIBUTION OF IRON, COBALT, BARIUM, STRONTIUM, ARSENIC, ANTIMONY, AND BISMUTH IN SAMPLES OF MINUS-60-MESH (0.25-MM) STREAM SEDIMENT AND (OR) NONMAGNETIC HEAVY-MINERAL CONCENTRATE, WALKER LAKE 1° X 2° QUADRANGLE, CALIFORNIA AND NEVADA

By

M.A. Chaffee, R.H. Hill, and S.J. Sutley

1988

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EXPLANATION
SAMPLE LOCALITY AND BOUNDARY AND DOMINANT LITH
ASSOCIATED DRAINAGE BASIN.--Anomalous in anti
Locality is at center of plotted symbol. Fi
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Solid outline indicates stream-sediment anom
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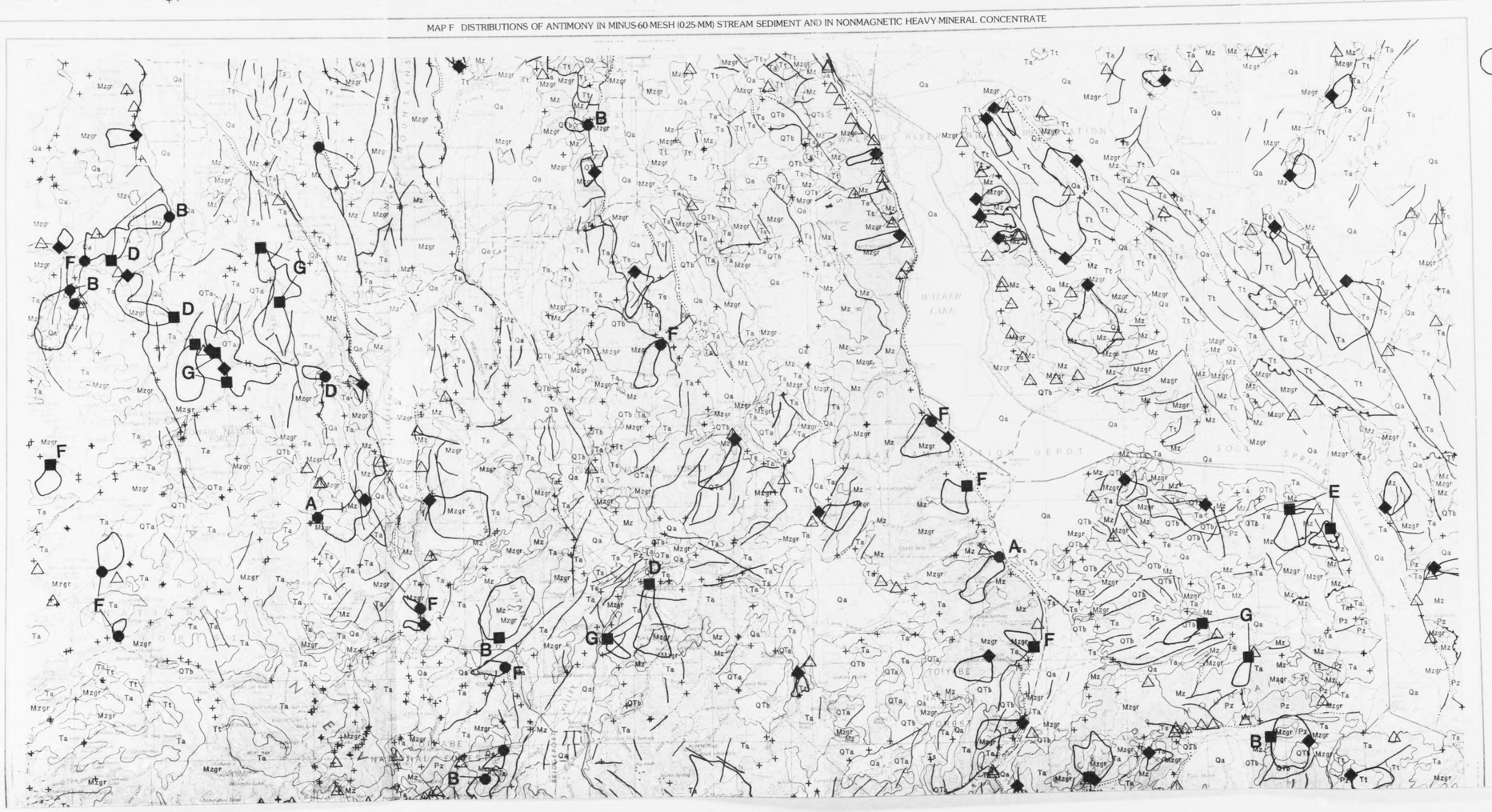
MAP F DISTRIBUTIONS OF ANTIMONY IN MINUS-60-MESH (0.25-MM) STREAM SEDIMENT AND IN NONMAGNETIC HEAVY-MINERAL CONCENTRATE


EXPLANATION
SAMPLE LOCALITY AND BOUNDARY AND DOMINAN
ASSOCIATED DRAINAGE BASIN.--Anomalous
Locality is at center of plotted sym
concentration ranges represented by
Letter indicates lithology keyed to
WALKER LAKE

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MAP F DISTRIBUTIONS OF ANTIMONY IN MINUS-60-MESH (0.25-MM) STREAM SEDIMENT AND IN NONMAGNETIC HEAVY-MINERAL CONCENTRATE

EXPLANATION

E — SAMPLE LOCALITY AND BOUNDARY AND DOMINANT LITHOLOGY OF ASSOCIATED DRAINAGE BASIN--Anomalous in antimony. Locality is at center of plotted symbol. Figure 4 shows concentration ranges represented by locality symbols. Solid outline indicates stream-sediment anomaly; dashed outline indicates concentrate anomaly (antimony ≥ N(200) ppm in concentrate samples). Letter indicates lithology keyed to table 1

Table 1.--Summary of the dominant source-rock type(s) present in the drainage basins upstream from the most metal-rich sample localities shown on the maps

[X indicates rock type present; leaders (--) indicate rock type not present in significant exposures in that area. Area H is considered to be anomalous only as a result of scrap-metal contamination]

Lithology symbol	Dominant rock types in area: Paleozoic and Mesozoic rocks	Mesozoic intrusive rocks	Tertiary volcanic rocks
A	X	X	X
B	X	X	--
C	X	--	X
D	--	X	X
E	X	--	--
F	--	X	--
G	--	--	X

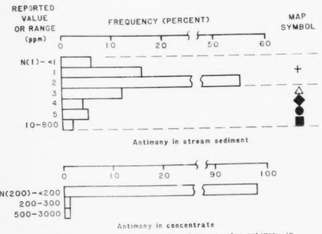

Figure 4.--Frequency-distribution histograms for antimony in samples of stream sediment and concentrate. N, not detected at lower limit of determination shown in parentheses. Darkened symbols indicate those concentrations considered to be anomalous.

EXPLANATION

B — SAMPLE LOCALITY AND BOUNDARY AND DOMINANT LITHOLOGY OF ASSOCIATED DRAINAGE BASIN--Anomalous in bismuth. Locality is at center of plotted symbol. Figure 5 shows concentration ranges represented by locality symbols. Letter indicates lithology keyed to table 1

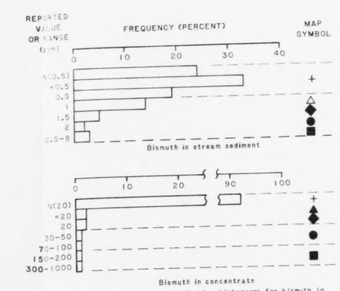

Figure 5.--Frequency-distribution histograms for bismuth in samples of stream sediment and concentrate. N, not detected at lower limit of determination shown in parentheses. Darkened symbols indicate those concentrations considered to be anomalous.

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MAP G. DISTRIBUTION OF BISMUTH IN MINUS-60-MESH (0.25-MM) STREAM SEDIMENT

MAP H. DISTRIBUTION OF BISMUTH IN NONMAGNETIC HEAVY-MINERAL CONCENTRATE

EXPLANATION

D — SAMPLE LOCALITY AND BOUNDARY AND DOMINANT ASSOCIATED DRAINAGE BASIN.--Anomalous in the locality is at center of plotted symbol. concentration ranges represented by letter. Letter indicates lithology keyed to table

Base from U.S. Geological Survey, 1957; revised 1969

Geology simplified from Stewart and others, 1982

MAPS SHOWING DISTRIBU
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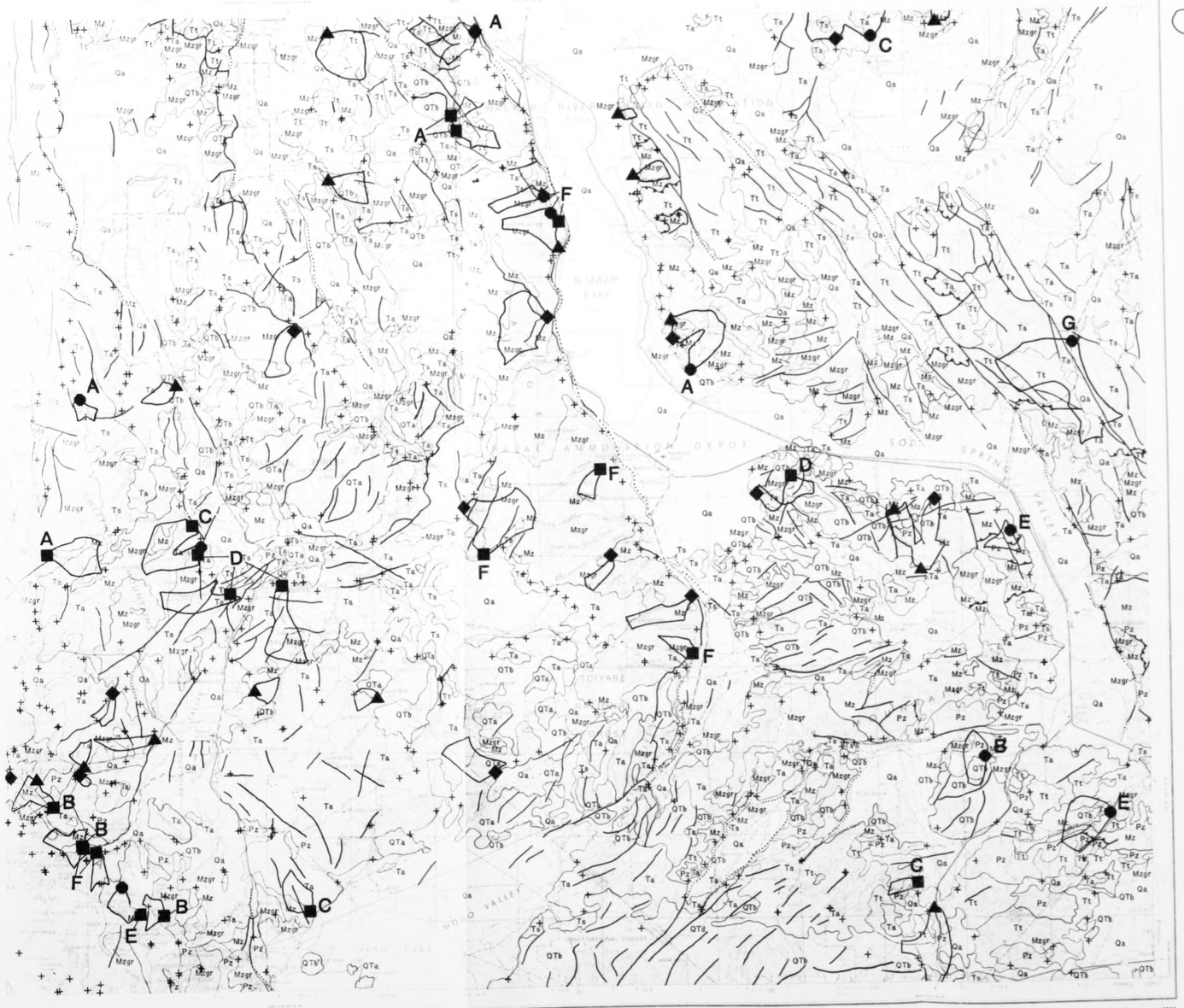
MAP G. DISTRIBUTION OF BISMUTH IN MINUS-60-MESH (0.25-MM) STREAM SEDIMENT



MAP H. DISTRIBUTION OF BISMUTH IN NONMAGNETIC HEAVY-MINERAL CONCENTRATE

Geology simplified from Stewart and others, 1982

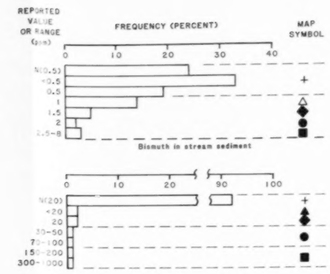


Figure 5.--Frequency-distribution histograms for bismuth in samples of stream sediment and concentrate. <, not detected at lower limit of determination shown in parentheses. Darkened symbols indicate those concentrations considered to be anomalous.

EXPLANATION

D SAMPLE LOCALITY AND BOUNDARY AND DOMINANT LITHOLOGY OF ASSOCIATED DRAINAGE BASIN--Anomalous in bismuth. Locality is at center of plotted symbol. Figure 5 shows concentration ranges represented by locality symbols. Letter indicates lithology keyed to table 1

Note: The following correlation and description of map units are for the geologic base map shown in gray

CORRELATION OF MAP UNITS

DESCRIPTION OF MAP UNITS

Qa ALLUVIAL, LACUSTRINE, EOLIAN, LANDSLIDE, AND GLACIAL DEPOSITS, UNDIVIDED (QUATERNARY)--As mapped locally includes uppermost Tertiary gravel

QTb BASALT (QUATERNARY AND TERTIARY)--Ranges in age from about 9 m.y. to less than 1 m.y.

QTa ANDESITE TO RHYOLITE (QUATERNARY AND TERTIARY)--Andesite flows and breccia. Minor rhyolitic flows and shallow intrusive rocks. Ranges in age from about 5 m.y. to less than 1 m.y.

Ts SEDIMENTARY ROCKS (TERTIARY)--Tuffaceous sandstone, siltstone, and conglomerate to gravel. Minor tuff and volcanic breccia. Ranges in age from about 12 m.y. to 2 m.y.

Ta ANDESITE TO RHYOLITE (TERTIARY)--Andesite flows and breccia. Minor rhyolitic flows and shallow intrusive rocks, latitic to rhyolitic ash-flow tuffs, and sedimentary rocks; sparse basalt; includes some intrusive rocks. Ranges in age from about 22 m.y. to 5 m.y.

Tt TUFF (TERTIARY)--Welded and nonwelded rhyolitic ash-flow tuff. Minor rhyolite flows and shallow intrusive rocks, andesite flows, and sedimentary rocks; sparse basalt; includes some intrusive rocks. Ranges in age from 30 m.y. to 22 m.y.

Mzgr GRANITIC ROCKS (MESOZOIC)--Granite to granodiorite. Minor diorite, gabbro, and felsic intrusive rocks

Mz VOLCANIC AND SEDIMENTARY ROCKS, UNDIVIDED (MESOZOIC)--Andesitic to rhyolitic lava flows, breccia, tuff, volcanic sandstone, and conglomerate; shallow marine siltstone, sandstone, conglomerate, and limestone; continental sandstone and conglomerate. Metamorphosed near granitic rocks

Pz SEDIMENTARY AND VOLCANIC ROCKS, UNDIVIDED (PALEOZOIC)--Deep-water marine chert, phyllite, shale, carbonate rocks, volcanogenic turbidite, sandstone, and conglomerate (Ordovician, Devonian, Pennsylvanian, and Permian); shallow-water siltstone, sandstone, conglomerate, and carbonate (Cambrian, Mississippian, and Permian; as mapped includes upper Proterozoic rocks at one locality); and andesitic breccia and lava (Permian). Metamorphosed near granitic rocks

GEOLOGIC CONTACT

HIGH-ANGLE FAULT--Dotted where concealed

THRUST OR LOW-ANGLE FAULT

QUADRANGLE LOCATION

SCALE 1:250 000

NATIONAL GEODETIC VERTICAL DATUM OF 1929
CONTOUR INTERVAL 200 FEET

MAPS SHOWING DISTRIBUTION OF IRON, COBALT, BARIUM, STRONTIUM, ARSENIC, ANTIMONY, AND BISMUTH IN SAMPLES OF MINUS-60-MESH (0.25-MM) STREAM SEDIMENT AND (OR) NONMAGNETIC HEAVY-MINERAL CONCENTRATE, WALKER LAKE 1° X 2° QUADRANGLE, CALIFORNIA AND NEVADA

By

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